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CARDIAC RHYTHM COMPUTER ANALYSIS TECHNIQUES

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16. Abstract

Both modern and ancient studies attest to the fact that cardiac rhythm may be accurately used to establish diagnosis of healthy and diseased conditions in man and animals.

Variational pulsometry, in conjunction with computerized data input, permits the scientist to utilize quantiative criteria and statistical parameters to refine this science.

The most sensitive parameters of cardiac rhythm were found to be strain, the coefficient of variation, and the percentage of dominance of sympathetic effects.

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CARDIAC RHYTHM COMPUTER ANALYSIS TECHNIQUES

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Ancient physicians seem to have distinguished between a hundred variations of pulse rhythm and even established diagnoses in terms of pulse. Modern studies [9-12, 14, 17-20] also attest to the informativeness of this parameter. The authors of these works concluded that we may judge the physiologically-related processes occurring in the entire organism in terms of such a cardio-vascular systemic parameter as cardiac rhythm. /254*

Variational pulsometry data has been successfully used in evaluating the psychologic strain of humans [1, 2, 9-11]. Variational pulsometry has been widely employed in diagnosing man's healthy and diseased condition [4, 7, 16]. The evaluation of pulse frequency disturbances by means of functional tests has been firmly adopted in medicine [5]. Ontogenic experiments run on animals indicated the high informativeness of cardiac rhythm in diagnosis of the functional condition of the animal organism [15]. Data which we obtained on humans confirmed the effectiveness of employing this parameter to solve different applied problems.

Until the present, no clear quantitative criteria have been developed; there has been insufficient definition of those statistical parameters which would permit maximum utilization of diagnostic information found in the sequence of signals characterizing the rhythm of cardiac contractions. The mathematical processing of cardiac rhythm data is also very difficult. Some of the more important statistical parameters of cardiac rhythm are now mainly performed manually, requiring a considerable expenditure

* Numbers in margin indicate pagination in original text.

of labor.

We will cite several quantitative criteria and statistical parameters of cardiac rhythm which were informative and have been employed in diagnosing the functional condition of man and animals. We will describe a semiautomatic system for computer input of graphic data which permits considerable deduction in data processing time.

Statistical Parameters of Cardiac Rhythm

In both manual and machine data processing of cardiac rhythm, it is primarily important to obtain statistical parameters which may be used to characterize the reliability of changes in cardiac arhythmia. The following characteristics are such parameters: the average arithmetic interval R-R ECG $\overline{T} = (1/N) \sum_{i=1}^{n} T_i$, where T_i is the time interval between R-R ECG peaks in succession; the empiric dispersion of interval duration $\sigma^2 \approx S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(T_i-\overline{T})^2$, the coefficient of asymmetry $g_s = \frac{\sum_{i=1}^{n}(T_i-\overline{T})^3}{n\sigma^3}$; mean deviation $m = \pm\frac{\sigma}{\sqrt{n}}$ and the coefficient of variation $CV = \frac{100\sigma}{\overline{T}}$ [13].

For a different type of quantitative comparison the cardiovascular systemic strain function was practical and was employed by many authors:

$$H = \frac{100}{T} \quad \text{(in balls)}.$$

Functional stress (S), expressed in relative units, is a direction function of pulse frequency and is defined by the mean duration of the ECG R-R interval. The stress parameter (S) is very sensitive to the least pulse disturbances.

A research method for studying the effects of various areas of the vegetative nervous system on the dynamics of cardiac contractions appears very promising. This method is based on the evaluation of the duration of transitional processes in cardiac /255 rhythm. The duration of the transitional process is evaluated with respect to accelerated, identical and decelerated contractions.

The method of evaluating vegetative effects on cardiac rhythmic structure rests on the fact that each interval between cardiac contractions is equalized in duration with the preceeding interval. Intervals T_i and T_{i+1} are considered identical so that we meet the following conditions: $/T_i - T_{i+1}/ < \Delta T$, where ΔT is defined by the difference with which T_i is measured, and also by requirements imposed on the analysis (in our case $\Delta T = 0.02$ s).

The percentage relationships of the intervals by durations are defined; henceforth this will be used to quantitatively evaluate the excess of sympathetic or parasympathetic divisions of the vegetative nervous system.

Computer Input of Graphic Information

We have developed a simple method for computer input of graphic data into a small computer of the 'Prominj' type (Fig. 1). It consists of a dual-coordinate recorder (1), type PDS-021 and a voltage--to-frequency converter (2), type F573.

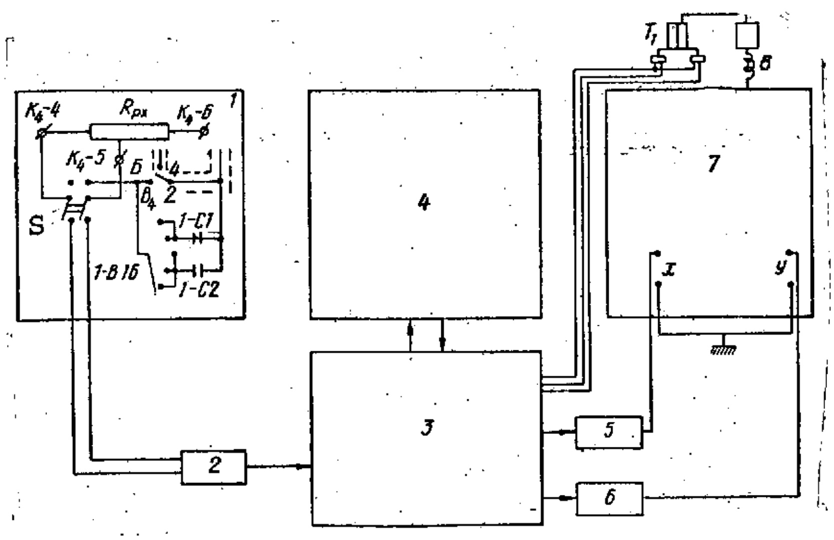

Fig. 1. Block Diagram of Graphic Input and Structure. 1,7 -- dual-coordinate recorder, PDS-021; 2 -- F573, voltage-to-frequency converter; 3 -- interface; 4 - computer; 5,6 --code-to-voltage converter; 8 -- pen solenoid.

Computer input of tape is performed as follows: tape from recorded ECG is wound on the recorder reel along the x axis; the motors of the servomechanism are controlled by the motor switch on the face-plate of the PDS-021. The recording pen is placed on each ECG peak in succession, using manual control. Then, with the motion of the slide wire R_{px} with respect to K_4-4, voltages are maintained proportional to the time coordinates of points to be input to computer storage. Voltage from the moving slide wire through switch S is fed to converter (2). A code corresponding to the frequency at the converter output is input to computer memory by the appropriate program, through a specially-developed interface (3) [6].

The time interval of the ECG R-R is defined as the difference in codes corresponding to peaks of two adjacent peaks and the scaling factor. The scaling factor is previously input into the computer memory by the operator or is defined using a special subprogram (or else into computer memory is input the coordinates of the time reference marks on the tape). If all peaks located in the tape segment wound on the recorder reel are thus input into the computer, the tape rolls on and the next tape segment peaks are input, and so forth. If it is necessary to input 2 coordinates, another voltage-to-frequency converter is attached to the circuit; a slide wire R_{py} is connected to it as with the first slide wire. The use of a voltage-to-frequency converter for encoding allows for enhancement of interference protection of the circuit against recurrent interference [8].

A block diagram of the graphic data computer input program /256
is illustrated in figure 2. The recording pen is set at the top of the first peak of the ECG R-R, then coordinates corresponding to this pen position are encoded upon command K_1 of the data input program and its value is written in element A. Input into the computer of the code corresponding to the coordinates of the next peak is performed during computer stop and travel of the recording

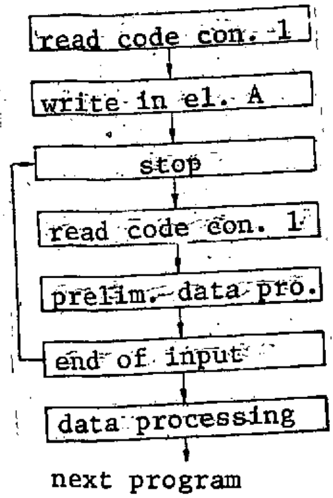

Fig. 2. Block diagram of computer data input program.

pen to the top of the next ECG peak. After writing the code which corresponds to the coordinates of the two peaks, the first time interval T_i is computed, which is written by the first address command "record of second order "(cf. description of 'Prominj' computer), and the value of the coordinates of the second peak are written in element A. Then the address is formed for the next time interval. The end of the data input is defined by the comparison of the formed address for each following interval with the number (n + 1) represented in the address form (n -- number of given intervals no greater than 79). If the input number of intervals is less than given, the computer stops, the recording pen moves to the summit of the next peak and waits until the necessary number of ECG R-R peaks are input. To simplify the processing program in some elements are accumulated the sum of all intervals. Then, to define each tape movement, the program begins with the command K_1. At the end of data input, a computation of the statistical parameters of cardiac rhythm is performed using the formulas cited above.

Information from the computer is extracted in the form of tables and graphs. To extract information from the computer in graphic form, a dual-coordinate recorder is used [7] and two code-to-voltage converters (5, 6) (Fig. 1). Control of the pen solenoid (8) is performed by trigger T. Since the converters may yield high voltages (1-10 V), some changes were made in the circuit to improve the quality of operation: voltage dividers taken from slide wires $1\text{-}R_{19}$, $1\text{-}R_{26}$ and $2\text{-}R_9$, $2\text{-}R_{26}$ are separated (cf. description of PDS-021); input transformers 1-tr, 2-tr, one half of lamp 1-L and 2-L, and the input divider are disconnected. Converters (5,6) are designed to convert codes using a floating decimal, since the 'Prominj' computer does not permit the translation of codes with floating decimal into codes with fixed decimal.

Due to the limited dynamic range of pen travel, a selection of scaling factors is made prior to graph construction: S_x, S_y along the y axis [3]: $S_x = \phi_x/x_{max}$, $S_y = \phi_y/y_{max}$, where

ϕ_x, ϕ_y -- codes corresponding to required size of graph;
x_{max}, y_{max} -- maximum values of data obtained.

If in data processing were allow successive computations of coordinates x and y for the required graph, its construction program may be reduced to such commands as: a) transmit code corresponding to X_1 coordinate to converter (5); b) transmit code corresponding to coordinate y to converter (6); c) drop recording pen; d) raise recording pen. These and other commands are performed in circuit (3).

This method of analysis of cardiac rhythm was used by us to diagnose the functional condition of animals and humans. Sensitivity of the statistical parameters was defined by their replacement by minor functional loads. Most sensitive parameters of cardiac rhythm on minor incremental loads were: strain (S) expressed in balls, coefficient of variation CV and the percentage of dominance of sympathetic effects.

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